

MODELING THE TEMPORAL AND SPATIAL VARIATIONS OF THE VERTICAL
STRUCTURE OF JUPITER'S ATMOSPHERE USING OBSERVATIONS OF
THE 3-0 HYDROGEN QUADRUPOLE LINES

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The presentation by Cunningham et al. is largely contained in a paper which has been submitted to *Icarus*. The abstract of that paper is reproduced here:

An observational program was established in 1983 to monitor the spatial and temporal variations in the Jovian atmosphere over short and long time scales. The program involves tracking several different longitudes as they rotate around the planet from one limb to another. This tracking experiment was done at many different wavelengths including the 3-0 S(1) and S(0) hydrogen quadrupole lines as well as several broad band methane absorptions. The June 1983 hydrogen quadrupole data has been reduced and equivalent widths have been measured for approximately 25 east-west positions across the planet at 7 different latitudes for both wavelengths. The data for the South Tropical Zone (20 deg S) has been modeled extensively and the effects of the various model parameters on the value of the calculated equivalent widths of both lines was measured as a longitude rotated from the east (or morning) limb to the west (or evening) limb. This increase may be indicative of a diurnal variation in the vertical cloud structure. One plausible explanation appears to be a gradual thinning of the upper NH₃ cloud during the day with the cloud rebuilding during the Jovian night. The value of the equivalent width is also quite sensitive to the height of the NH₃ cloud top and to the value used for the single scattering albedo. A combination of these parameters changing on a diurnal time scale could also explain these observations. This gradual increase from one limb to the other appears in the data for both the North and South Equatorial Belts as well as the equatorial region and the North Tropical Zone. Finally, models that used only normal hydrogen and models that used only equilibrium hydrogen were studied. For all regions the models that used equilibrium hydrogen throughout the vertical structure (between 0 and 2000 mb) fit both quadrupole lines better than the models that used normal hydrogen throughout.

DR. POLLACK: Let me make a mostly philosophical comment on techniques of computing cloud structure based upon work that you'll hear on Wednesday for Uranus. We are working with many free parameters when we try to infer cloud structure in a realistic outer planet. So you need to have as many different types of observational constraints as possible if you are to obtain unambiguous results. For review purposes, it might be nice for you in future work to get data also in methane absorption bands so you can really have enough constraints to pull out what you want.

MS. CUNNINGHAM: We got methane data at the same time as our quadrupole data. It just hasn't been reduced yet.

DR. W. H. SMITH: Bill Cochran and I have a very similar set of data showing the center-to-limb variation of the $S_3(1)$ feature. Recently, I and my co-workers at Washington University have obtained the required laboratory data for interpreting the spectra quantitatively. This includes low temperature measurements of the pressure broadening and shift coefficients for ammonia, methane, and hydrogen at 80 K. Also, the line assignments for the 6450 Å ammonia band are now known. So, with the laboratory data requirements being largely met, we can restrict the number of free parameters much further and can specify the ambient conditions for the lower cloud in terms of pressure, temperature and approach to thermodynamic equilibrium. The only free parameters left are those related to the scattering characteristics of the clouds, their placement, the effective transport processes of the atmospheric gases and cloud particles.

MS. CUNNINGHAM: Are you adding diurnal effects as well?

DR. SMITH: Our original data set was obtained several years ago before CCD's were available, so we have a less extensive data set than you. We also averaged over a range of longitude as well. However, the general shape of the center-to-limb variation is the same, except for the tilt from center to limb which you are tentatively ascribing to a diurnal effect. We do not see any evidence for that effect at the time of our observation. Our analysis has included NH_3 and CH_4 profiles as well. The added constraints on the models has been useful to reduce the range of models which plausibly fit the observations.

DR. LUNINE: You say that your results are not sensitive to the base of the water cloud when you varied the base from something like 1600 to 2400 millibars. Can you rule out a cloud that goes much deeper?

MS. CUNNINGHAM: Our data cannot rule that out, but Gordon Bjoraker has done a very thorough analysis of the deeper regions in the Jovian atmosphere using Voyager data. Our placement of the lower cloud at about 2 bars is based, at least in part, on his work.

DR. LUNINE: Well, I was asking because I was wondering if you have any sensitivity to the cloud level at all and could provide an independent assessment of Gordon's H_2O abundance determinations.

MS. CUNNINGHAM: We can change the pressure at which the lower cloud forms if we also modify the thickness or height of the upper ammonia cloud. There are several families of workable models that will fit the data. At the present time we have constrained the position of the bottom cloud using observations that are more sensitive to that particular region in the atmosphere. It may be possible to make additional constraints on the position of this lower cloud using our broad-band methane data.

DR. INGERSOLL: I hate to use theoretical arguments to shoot down good observations, but diurnal variation at these tropospheric levels are quite hard to

understand. I'm wondering if there is any possible systematic effect between east limb and west limb.

MS. CUNNINGHAM: I've looked pretty carefully because I read about that a lot, too. These bands form a part of the spectrum that is fairly clear of water lines. I obtained some very high air mass solar spectra to look for very small features that might be interfering and affecting the equivalent width of the lines. The region is very clear. This (June) 1983 data is some of our best with respect to the consideration of which part of the spectrum shows a Doppler shift of the quadrupole lines.

DR. BAINES: I discussed similar data, as Bill has mentioned, two years ago. We found then that the observations were very symmetrical from one limb to another. The difference I'm saying here is that we have an equatorial region, but looking at your equatorial region data, you get about 20% greater equivalent width than what we saw. That corresponds to a decrease, as you model it there, to the optical depth of the cloud; I had more like nine, and you are talking about six. I think there is probably a one-to-one correspondence between points. So maybe there is something going on in time there, and maybe that agrees with Reta Beebe and what Glenn Orton showed; that the equatorial region is sort of clearing over a span of three or four years. This data set was taken in 1978, so maybe there is some sort of temporal long-term thing there that we are really quantitatively modeling.

MS. CUNNINGHAM: The equatorial region appears to be a combination of both a belt and a zone. I picked out three particular longitudes to do my tracking experiment. Perhaps these particular longitudes just happened to be more zone-like than belt-like.

DR. WEST: I'd like to follow up Andy's question. It seems to me that one of the most controversial conclusions you come to is the diurnal variation. I'm not aware of any other observations that show that. Are you?

MS. CUNNINGHAM: No. That's why I plan to start looking into our other data in the next few months.

DR. LEOVY: I am concerned about the amplification of the sensitivity for overlying haze. Have you really ruled out the possibility that it is these overlying haze parameters that are causing the diurnal variation?

MS. CUNNINGHAM: I've tried models which distribute the haze over the region from the top of the atmosphere to the top of the ammonia cloud and the calculated equivalent widths were no different than those evaluated with models that had the haze in a concentrated layer. I have also tried models with haze thicknesses that were a factor of four higher than those used in our "best fit" models and the calculated equivalent widths also appear to be insensitive to any reasonable changes in haze thickness.